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ASSISTED BY A COMMITTEE OF COUNCIL.

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1914.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 16, 1914, *at* 5 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

Mr. Alexander Miers Macgregor was provisionally elected an Ordinary Member of the Society.

The following changes in the list of Officers and Council were approved for recomendation to the Members of the Society: Messrs. Evans, Hatch, Howe, and Campbell Smith, in place of the four retiring members of Council (Messrs. Barlow, Crook, and Herbert Smith, and Sir Thomas Holland).

The President was appointed as delegate to represent the Society at the International Congress of Mining, &c., to be held in 1915.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 16, 1914, *at* 5.30 *p.m.*

Dr. A E. H. Tutton, M.A., F.R.S., President, in the Chair.

Twenty-four Members and four Visitors were present.

The election of Mr. A. M. Macgregor as an Ordinary Member of the Society was confirmed.

The following papers were then read:—

1. Childrenite from Crinnis mine, Cornwall, and Eosphorite from Poland, Maine: by Dr. J. Drugman.

2. On Sartorite: by Mr. R. H. Solly.

3. Re-determination of nickel in the Baroti and Wittekrantz meteorites by Dr. G. T. Prior (p. 127).

4. A new locality for Voelckerite and the validity of Voelckerite as a mineral species: by Prof. A. F. Rogers (p. 155).

5. On Epidote from the Sudan: by Mr. H. B. Cronshaw.

6. Hæmatite crystals from the Kajlidongri manganese mine, India; and ice crystals from Switzerland: by Dr. L. L. Fermor (p. 150).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 10, 1914, *at* 5 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

The following were selected as the dates of meeting for the year 1915: Tuesdays, January 26, March 16, June 15, and November 9, the last to be the Anniversary Meeting.

The draft Annual Report of Council, submitted by the Secretary, was approved.

A vote of thanks was passed to Dr. G. F. Herbert Smith for sending notices of the meetings of the Society to 'Nature', 'The Geological Magazine', 'The Mining Journal', and 'Centralblatt für Mineralogie'.

Resolved to place The United Service Institution of India (Simla) on the list for presentation of the Journal.

The President announced the change of name of Friedrich Noel Ashcroft Fleischmann, a Trustee and Member of Council, to that of Frederick Noel Ashcroft.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 10, 1914, *at* 5.30 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

Twenty-one members and three Visitors were present.

The President nominated Messrs. Barker and Collingridge to act as scrutineers of the voting-papers for the election of Officers and Council. The scrutineers reported that forty-four voting-papers had been returned to the Secretary, and that the list as nominated by the Council was approved, namely:

President. A. E. H. Tutton, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. H. L. Bowman, M.A., D.Sc., F.G.S.
A. Hutchinson, M.A., Ph.D., F.G.S.

Treasurer. Sir William P. Beale, Bart., K.C., M.P., F.G.S., F.C.S.

General Secretary. G. T. Prior, M.A., D.Sc., F.R.S.

Foreign Secretary. Prof. W. W. Watts, LL.D., Sc.D., F.R.S.

Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

F. N. Ashcroft, M.A., F.C.S.
F. H. Butler, M.A., A.R.S.M., L.S.A. (Lond.)
J. P. De Castro, M.A., F.I.C., F.C.S.
J. W. Evans, LL.B., D.Sc., F.G.S.
Prof. H. Hilton, M.A., D.Sc.
F. H. Hatch, Ph.D., F.G.S.
J. Allen Howe, B.Sc., F.G.S.
B. Kitto, F.I.C., F.G.S.
Prof. A. Liversidge, M.A., LL.D., F.R.S.
Arthur Russell.
W. Campbell Smith, M.A., F.G.S.
J. J. Harris Teall, M.A., LL.D., D.Sc., F.R.S.

The following ANNUAL REPORT OF COUNCIL was read:—

During the Session 1913–14 four meetings have been held (by kind permission) in the Apartments of the Geological Society, Burlington House, W., at which nineteen papers were read. Two numbers of the Journal, viz. No. 78 published in December and No. 79 in July, have been issued. These contain thirteen papers, together with notes and reviews, and a new list of members. Half the cost of the three plates illustrating his paper on the minerals found in the Virtuous Lady mine was defrayed by Mr. Arthur Russell.

The balance-sheet of the year ending December 31, 1913, shows that the financial position of the Society continues to be satisfactory. The assets (exclusive of the Library and stock of the Journal) amounted to £889 0*s.* 2*d.*, and the liabilities to £13 9*s.* 1*d.* The value of the stock invested in the names of the Trustees of the Society was on that date £765 10*s.* 0*d.*, corresponding to £14 3*s.* 6*d.* for each Life-Member. During the Session a donation of £5 was voted towards the expenses of publication of the International Tables of Constants.

During the Session 1913–14 the Society has lost by death one Honorary Member, Prof. H. Rosenbusch, and one Ordinary Member. Seven Ordinary Members have been elected. The total number of members on November 9, 1914, was 148, of whom seventeen are Honorary. Of the Ordinary Members fifty-four have compounded for their annual subscription.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Mr. Butler, seconded by Prof. Bowman, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried.

The dates of meeting for 1915, proposed by the Council, were approved.

The following papers were then read:—

1. Albite: its crystal elements, etc.: by Prof. J. W. Lewis.

2. The determination of the maximum extinction, etc., of monoclinic pyroxenes in thin sections: by Mr. H. Collingridge (p. 147).

3. Note on Calcite from the Chalk at Corfe Castle, Dorset: by Prof. H. L. Bowman (p. 135).

4. Barkevikite from Lugar, Ayrshire; and Litharge from Persia: by Mr. A. Scott (pp. 138, 143).

5. Meteorites of Kota Kota, Uwet, and Angela; the identity of Angela and La Primitiva: by Dr. G. T. Prior (p. 127).

Specimens illustrating their papers were exhibited by Prof. Lewis, Prof. Bowman, and Mr. Scott.

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 80. DECEMBER, 1914. Vol. XVII.

The Meteorites of Uwet, Kota Kota, and Angela: re-determinations of nickel and iron in the Baroti and Wittekrantz meteoric stones.[1]

(*With Plates V and VI.*)

By G. T. Prior, M.A., D.Sc., F.R.S.

Keeper of the Mineral Department of the British Museum.

[Read June 16 and November 10, 1914.]

1. The Meteoric Iron of Uwet, Southern Nigeria.

EARLY in 1905 a small fragment of a meteoric iron from Uwet in Southern Nigeria was received at the Imperial Institute from Mr. John Parkinson, the Principal of the Mineral Survey then proceeding in Southern Nigeria. The fragment was part of a large mass which was held in great veneration by the natives of Uwet (lat. 5° 17′ N., long. 8° 15′ E.), a town on the Calabar river, about 23 miles north by west of Calabar. Later, further particulars of the meteorite were communicated to the Imperial Institute by Mr. E. D. Simpson. According to Mr. Simpson's report, dated March 30, 1907: 'About eighty years ago a meteorite fell at Uwet causing considerable consternation. A large hole was noticed but was not probed. The same day a second fell which is the one in question. In this case it was dug up and preserved. No further details are remembered. The time of year was about June or

[1] Communicated by permission of the Trustees of the British Museum.

May—the end of the tornado season. The stone is not "juju," but is bound up in the general welfare of the town. In 1903 it was removed from Uwet. Smallpox, however, broke out and devastated the town, which was attributed to its absence. The stone was returned to Uwet, since when, I am informed, the town has been entirely prosperous.'

The mass was of irregular shape, as shown in the photographs (Plate V, figs. 1 and 2). Mr. Simpson gave the following measurements: circumference, lengthways 3 ft. 6 in., breadthways 1 ft. 9 in.; length about 1 ft. 3 in.; breadth about 9 in. The weight was estimated to be 120 lb.

At the suggestion of Dr. L. Fletcher, at that time Keeper of the Mineral Department of the British Museum, to whom the fragment had been submitted for examination, request was made by the Director of the Imperial Institute, Prof. W. R. Dunstan, to the authorities in Southern Nigeria that, after friendly arrangement with the natives, a corner should be sawn off the meteoric iron for preservation and examination. This request was acceded to, and a portion of the meteorite weighing about 20 lb. was forwarded to the Imperial Institute. In February 1908, through the kindness of Prof. Dunstan, the mass was transferred to the British Museum as a donation from the Governor of Southern Nigeria.

Physical Characters.

The specimen sawn from the original mass was a roughly conical piece having a height of about 4 inches and an oval base of 6 to 6¾ inches diameter. Its surface is smooth and rounded, and is only partially covered with a thin black film of oxide. The iron is bright, shows no signs of weathering, and is free from large inclusions. On the polished surface of the base are seen about ten small inclusions of troilite, the largest of which does not exceed 16 mm. in length and 4 mm. in breadth. Schreibersite (rhabdite) is distributed uniformly over the slice in fine needles up to a centimetre in length. These are mostly parallel to one direction, but a few occur parallel to a direction nearly at right angles, and a third set of shorter needles, still less prominent, at an angle of about 24° with the direction of the first set. Etching with bromine of a small polished slice of the iron developed Neumann lines to perfection. The slice was densely covered with sets of fine parallel lines. Two sets are most prominent, traversing the slice from side to side and inclined to each other at about 30°. One of these is inclined to the main set of schreibersite needles at an angle of about 54°, and the other is parallel

to the shorter needles. A third set of shorter etched lines in places cuts the first two sets at angles of about 80° and 70° respectively, and a fourth set, much less distinct, can be faintly distinguished cutting the third set at about 26°. The iron thus belongs to the normal hexahedrite group, of the type of Braunau.

The density of a piece of the iron, weighing about 20 grams and as free as possible from troilite, was 7·862.

Chemical Composition.

For the chemical analysis, about 8 grams of the iron free from troilite was dissolved in aqua regia, filtered from a slight residue of carbonaceous matter and divided into five equal portions. In one of these portions the nickel was determined by precipitation with dimethylglyoxime; in another the iron was separated from the nickel and cobalt by a double precipitation with sodium acetate, and the nickel from the cobalt by means of dimethylglyoxime. The result of the analysis is as follows:

Fe	93·36
Ni	5·78
Co	0·75
Cu	nil
P	0·25
Carbonaceous matter ...	0·03
	100·17

The meteoric iron of Uwet is a hexahedrite of the Braunau type, showing, on etching, well-marked Neumann lines, and having a chemical composition approximating to $Fe_{14}Ni$, and a density of 7·862.

2. The Meteoric Stone of Kota Kota, Marimba district, British Central Africa.

In 1905, besides the meteoric iron from Uwet, the Imperial Institute received from Africa a stone said to be of meteoric origin. The specimen was sent by the Acting Commissioner for British Central Africa, who stated that it fell some years previously in the Marimba district, British Central Africa, where it was found by the District Commissioner, and that the original stone had since been broken up by the natives. Through the kindness of Prof. Dunstan, the specimen was transferred to the British Museum as a donation from Mr. A. J. Swann, the magistrate of

the Marimba district, who had obtained the specimen from the natives. According to information supplied by Mr. Swann in answer to inquiries made by Dr. Fletcher, some natives with whom he was conversing about meteorites in order to ascertain if any were known to them, said: 'There was a large one in our district, but that, as it was God's stone and came from the air, it was kept a secret by a Chief and protected.' Mr. Swann was a year in trying to locate the stone, but at last succeeded in inducing two natives to make a journey of 95 miles to fetch it. They returned with the specimen lashed to a pole and said that it was only a piece of the original stone which fell. Nothing would induce them to touch it, and when Mr. Swann suggested that it was simply an ordinary piece of country rock they said: 'Master, do not disbelieve us. We have done our journey as you must know, and that stone is a piece of the great stone which every one knows fell near our villages but which is not to be taken away by any one. We went because you say you are not afraid of our spirits. Take care of it.' The precise locality in the Marimba district where the stone fell was given by Mr. Swann as Kota Kota, Lake Nyasa (lat. 12° 55′ S., long. 34° 18′ E.).

The specimen, which weighs 333 grams, is much weathered and rusted, but has the appearance of being a nearly complete stone rather than a fragment broken from a larger one. It is of irregular shape and shows on certain faces traces of the original black fused crust. One smooth corner where three somewhat concave faces meet is preserved intact, but the other corners of the stone have been broken off and show a 2 mm. thick layer of hard rust. Small sharply defined chondrules are seen projecting from the surface in several places. A thin slice shows numerous small sharply defined chondrules and sections of pyroxenes in a rusted matrix. Most of the larger chondrules are of fibrous radiating rhombic pyroxene, but the smaller ones consist mainly of grains of a pyroxene which shows a well-marked longitudinal cleavage and between crossed nicols a lamellated structure like a plagioclase felspar, and is thus similar to the pyroxene (γ) described by Prof. H. L. Bowman as occurring in the Chandakapur meteoric stone.[1] The stone probably belongs to the group of spherulitic chondrites and in character is distinct from the meteoric stone of Mt. Zomba, British Central Africa, a locality about 150 miles south of Kota Kota. Owing to the weathered and rusted condition of the stone no chemical analysis was made, as it would have been of little value.

[1] H. L. Bowman, Mineralogical Magazine, 1910, vol. xv, p. 355.

3. The Meteoric Iron of Angela, Santa Catalina, Iquique, Chili, and its probable identity with La Primitiva.

In 1904 the British Museum[1] became possessed of a mass of meteoric iron weighing 4,065 grams which had been sent to Mr. Martin Hardie, of London, by his uncle Mr. William Hardie in Iquique, Chili. According to Mr. W. Hardie's letter, the mass of iron 'was found in the jaws of one of the crushers of the Angela Nitrate Co., Ltd., at the Oficina Angela, and was picked out in time to save broken plates. It had been carted a distance of half a mile along with the caliche or raw material from which nitrate of soda is produced. It must have been embedded in a mass of caliche, for it had a little caliche sticking to it. . . . The Oficina Angela is an establishment for producing nitrate of soda from the caliche extracted from its surrounding grounds inside a half circle with a radius of two miles, more or less. . . . The aerolite was picked up half a mile from the "maquina" or plant, which is situated in the district of Santa Catalina, Tarapaca, at a distance of 41 miles by the Nitrate Railway line from Pisagua, and, as the crow flies, 40 miles N.E. from Iquique.' In 1906 and 1911 two other masses of the same meteoric iron weighing respectively 1,480 and 4,341 grams were obtained by the Museum from the same source.

Physical Characters.

The three masses are all of very irregular shape, with jagged pieces of iron projecting from the main mass (see Plate VI, fig. 1). This structure appears to be due to the fact that in each case the iron is honeycombed by schreibersite, which in one piece is estimated to amount to nearly a quarter of the mass. Etching with bromine of a polished surface of the iron gives it a satiny appearance, but develops no Widmanstätten figures, nor typical Neumann lines, though in parts faint indication of parallel lines and of curved lines like finger-prints can be observed with the lens. The iron is therefore an ataxite.

The density of a piece of the iron, weighing about 10 grams and as free as possible from schreibersite, was 7·892.

Chemical Composition.

A chemical analysis of the iron, as free as possible from schreibersite, gave the following numbers under I; under II for comparison is given the result of the analysis of La Primitiva made by O. Sjöström.[2]

[1] In the British Museum 'Introduction to the study of Meteorites,' 10th edition, 1908, this iron is referred to as 'Angelas (Oficina), Chili.'

[2] E. Cohen, 'Meteoreisen-Studien VI.' Ann. Naturhist. Hofmus. Wien, 1897, vol. xii, pp. 122–123.

	I. Angela.	II. La Primitiva.
Fe	95·03	94·72
Ni	4·52	4·72
Co	0·65	0·71
Cu	—	trace
C	trace	0·03
S	—	0·02
P	trace	0·18
	100·20	100·38

The result of the investigation shows that the Angela meteoric iron is an ataxite having a comparatively low percentage of nickel and characterized by its extraordinary richness in schreibersite. In these characters and in its chemical composition it appears to be identical with La Primitiva, the iron described by Cohen.[1] La Primitiva (lat. 19° 57′ S., long. 69° 50′ W.) is another of the nitrate works near Iquique and distant from the Angela (lat. 19° 48′ S., long. 69° 58′ W.) works about 12 miles. Photographs of etched polished surfaces of the two irons (Plate VI, figs. 2 and 3) show their similarity and the remarkable intergrowths of schreibersite.

4. Chemical Analysis of Meteoric Stones: re-determinations of Nickel and Iron in the Baroti and Wittekrantz Meteorites.

In a previous paper on the Baroti and Wittekrantz meteorites (this vol., p. 22), a simplified method of analysis of meteoric stones is described. For such analyses in which the extreme of accuracy was not required, it was thought that the separation of iron and nickel by repeated precipitation of the iron with ammonia would give sufficiently exact results and the introduction of large amounts of sodium acetate into the solutions be avoided. Almost immediately after the publication of that paper, however, it was found that the separation of the iron and nickel by means of ammonia had been by no means complete, and that it could not be made so even after as many as six or seven precipitations.[2] Accordingly in

[1] E. Cohen, loc. cit.

[2] C. Friedheim (Sitz-Ber. Akad. Berlin, 1888, p. 345) has stated that six or seven precipitations are necessary for absolutely complete separation; L. H. Borgström, that three or four may suffice if the solution after the addition of ammonia be kept for one to two hours on the water-bath. My experience suggests that by ammonia a really complete separation is scarcely possible.

the description of the method of analysis given in the previous paper, for the ammonia method of separating iron and nickel should be substituted the more accurate method of a triple (or even fourfold) precipitation with sodium acetate[1] or ammonium formate,[2] and subsequent precipitation with ammonia. The use of dimethylglyoxime,[3] although convenient for the precipitation of nickel, has the disadvantage that the cobalt passes into the filtrate with the iron, from which it would have to be subsequently separated. This reagent, however, may be used with advantage for the separation of the nickel and cobalt after the iron has been removed by sodium acetate, or for the precipitation and estimation of the nickel in a separate portion of the original solution.

In the case of the Baroti and Wittekrantz meteorites, in order to test the purity of the ferric oxide obtained in the analyses of the attracted portions after repeated precipitation with ammonia, it was brought into solution and treated for the separation of iron and nickel by the sodium acetate method. In both cases considerable amounts of nickel were found in the filtrates. The new determinations for the 'attracted portions' are :

	Baroti.	Wittekrantz.
Fe	67·20	56·75
Ni	10·35	8·82
Co	0·37	0·20

and in the 'unattracted portion' of Wittekrantz : Fe (in the nickel-iron), 0·31 ; FeO, 16·00 ; total, 100·43. Introducing these corrections, the bulk analyses and the mineral composition become (*see* p. 134) :

It is probably the case that in many analyses of meteoric stones the nickel has been under-estimated, especially when the ammonia method of separation from the iron has been used. The proportion of iron to nickel in most chondritic meteorites therefore probably approximates more closely to 6 : 1 than to the 10 : 1 suggested in a previous paper (this vol., p. 38).

[1] L. Fletcher, Mineralogical Magazine, 1901, vol. xiii, p. 11.

[2] As advocated by L. H. Borgström, Bull. Comm. Géol. Finlande, 1903, vol. iii, p. 73.

[3] Zeits. Anal. Chemie, 1908, vol. xlvii, p. 162.

Bulk Analyses.

	Baroti.	Wittekrantz.
SiO_2	39·64	41·12
TiO_2	0·16	0·17
Al_2O_3	2·40	2·54
Fe_2O_3	0·44	0·48
Cr_2O_3	0·18	0·36
FeO	13·99	14·73
MnO	trace	0·15
CaO	1·79	2·12
MgO	24·71	25·40
Na_2O	0·91	1·16
K_2O	0·04	0·14
P_2O_5	0·25	0·16
H_2O	0·17	0·16
FeS S	2·47	1·26
FeS Fe	4·32	2·20
Fe	7·70	7·10
Ni	1·19	1·11
Co	0·04	0·02
	100·40	100·38

Mineral Composition.

Baroti.			Wittekrantz.		
147 $Na_2O.Al_2O_3.6SiO_2$	7·70		187 $Na_2O.Al_2O_3.6SiO_2$	9·81	
4 $K_2O.Al_2O_3.6SiO_2$	0·22	10·25	15 $K_2O.Al_2O_3.6SiO_2$	0·83	11·95 Felspar.
84 $CaO.Al_2O_3.2SiO_2$	2·33		47 $CaO.Al_2O_3.2SiO_2$	1·31	
27 $FeO.Fe_2O_3$	0·63		30 $FeO.Fe_2O_3$	0·70	Magnetite.
20 $FeO.TiO_2$	0·31		21 $FeO.TiO_2$	0·32	Ilmenite.
12 $FeO.Cr_2O_3$	0·27		23 $FeO.Cr_2O_3$	0·52	Chromite.
$\frac{1}{3}$ $Ca_3 2PO_4.CaO$	0·56		$\frac{1}{3}$ $3Ca_3 2PO_4.CaO$	0·37	Apatite.
179 $CaSiO_3$	2·08		296 $CaSiO_3$	3·43	
534 $FeSiO_3$	7·03	30·38	437 $FeSiO_3$	5·77	26·60 Bronzite.
2127 $MgSiO_3$	21·27		1742 $MgSiO_3$	17·40	
675 Fe_2SiO_4	13·77		768 Fe_2SiO_4	15·66	
2025 Mg_2SiO_4	28·35	42·12	2304 Mg_2SiO_4	32·29	47·95 Olivine.
FeS	6·79		FeS	3·46	Troilite.
Fe	7·70		Fe	7·10	
Ni	1·19	8·93	Ni	1·11	8·23 Nickel-Iron.
Co	0·04		Co	0·02	
H_2O	0·17		H_2O	0·16	Water.
	100·41			100·26	

Fig. 1.

Fig. 2.

G. T. Prior: The Meteoric Iron of Uwet, Southern Nigeria.

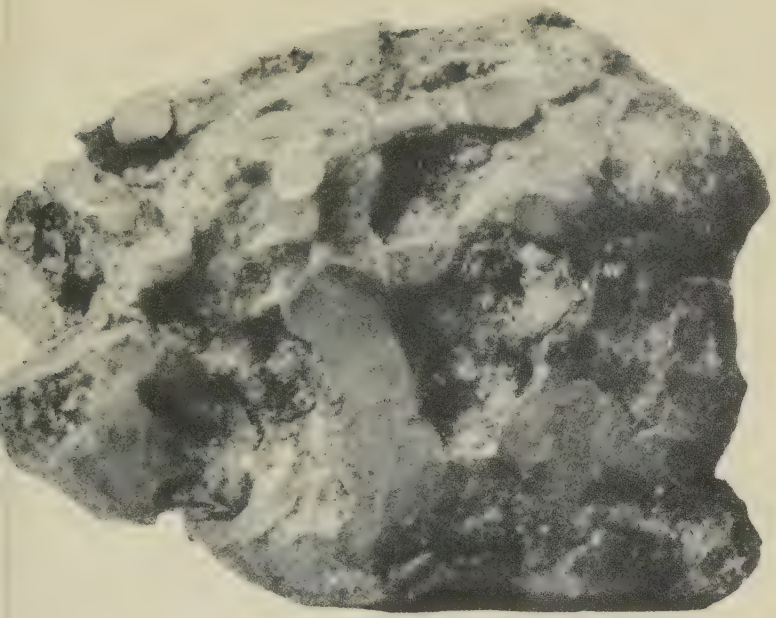
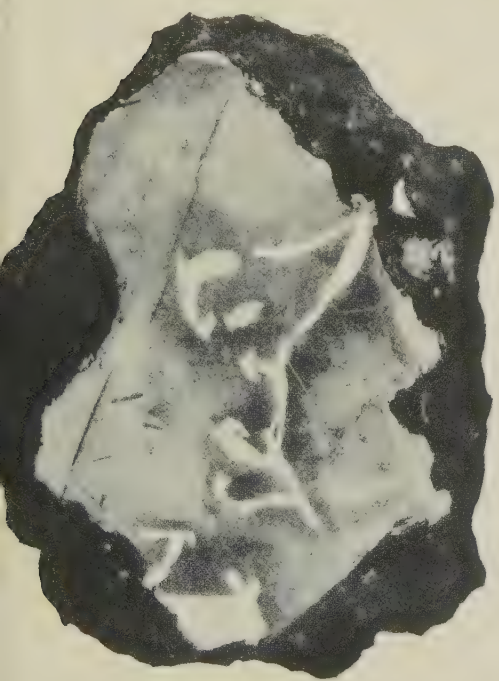


Fig. 1.—Meteoric Iron of Angela, Chili. ($\frac{1}{3}$ natural size.)



2.—Etched surface of the Angela Meteoric Iron showing Schreibersite. (Natural size.)

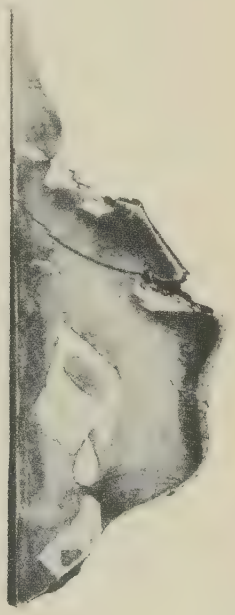


Fig. 3.—Etched surface of the La Primitiva Meteoric Iron showing Schreibersite. (Natural size.)

Communications from the Oxford Mineralogical Laboratory, No. XXIV.[1]

Note on Calcite from the Chalk at Corfe Castle, Dorset.

By H. L. Bowman, M.A., D.Sc.
Professor of Mineralogy in the University of Oxford.

[Read November 10, 1914.]

SOME specimens of calcite which I obtained recently from a chalk-pit at Corfe Castle in Dorsetshire appear worthy of description on account of their somewhat unusual habit and of the rarity of well-crystallized minerals in the Chalk.

The pit is situated in the Upper Chalk, not far from the great overthrust fault which traverses the Isle of Purbeck from west to east along the boundary of the Chalk and the overlying Tertiary beds. The Chalk is here steeply inclined, with a northerly dip, and is much indurated, being sufficiently hard to be worked for road-metal. The hardness is attributed by Strahan[2] to a crushing of the rock in the neighbourhood of the fault and subsequent re-cementing by carbonate of lime. An analysis of the hard chalk of this locality by Duvillier[3] shows: $CaCO_3$, 98·17; $MgCO_3$, 0·74; phosphate of lime, 0·26; oxide of iron, 0·28; soluble silica, 0·10; clay, 0·42 per cent.

The crystals occur in small veins partly filled with red clay with which they are often stained on the surface though clear and colourless within. They are usually about $\frac{1}{2}$ in. in diameter, but some attain a size of 1 in. in diameter by $1\frac{1}{2}$ in. in length, and they include some pretty examples of 'ghost crystals', in which a nucleus of the same form as the crystal is outlined by a layer of brownish particles.

The predominant forms are the steep inverse rhombohedron $f\ \{11\bar{1}\}$ and the scalenohedron $x\ \{21\bar{2}\}$, whose faces lie in the zone of the rhombohedral edges and make an angle of 17° 5′ with the faces of f (measured

[1] No. XXIII of this series appeared in this vol., p. 100.

[2] A. Strahan, Geological Survey Memoir of the Isle of Purbeck, 1898, p. 169.

[3] C. Barrois, 'Recherches sur le terrain crétacé supérieur de l'Angleterre et de l'Irlande.' Mém. Soc. Géol. Nord, 1876.

angles varied between 16° 42′ and 17° 2′). In some crystals the forms f and x are equally developed, as shown in fig. 1; in others the rhombohedron predominates, and many have the appearance of three-sided pyramids, having no more than the upper third of the rhombohedron developed, usually modified below by faces of x. The faces of f are smooth and bright, and give perfect images of the goniometer-signal: those of x are usually somewhat uneven. A few crystals show also small faces of a steeper inverse rhombohedron, $d\{335\}$, which make an angle of 52° 37′ with the cleavage (observed angle 52° 32′).

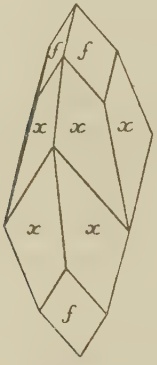


Fig. 1.

Fig. 2.

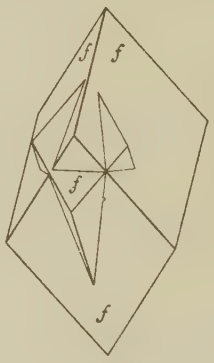


Fig. 3.

Some of the crystals, usually of rhombohedral habit, show twinning about the axis [111], the two individuals being interpenetrant, as in the well-known crystals of cinnabar from China. The interpenetration is somewhat irregular, and corners of one individual project through the faces of the other (fig. 3). These crystals are frequently dull and much rounded, their uneven faces presenting a marked contrast to the brilliant faces of the untwinned crystals.

One group of two crystals with non-parallel axes appears to be a twin on e (110), with contact along an uneven surface transverse to the twin-plane.

The crystals are frequently traversed by twin-lamellae parallel to planes of $e\{110\}$, and the lamellae are generally marked by grooves in the surface, due to corrosion. Similar grooves are sometimes also developed along planes of {100}, by corrosion along cleavage-cracks. Well-defined tched pits, of curved triangular form (fig. 2), are sometimes to be seen n bright faces of f. On the other hand, faces of the rhombohedron

{100} (perhaps due to cleavage), which are sometimes visible on the edges of *f*, are always roughened and drusy by corrosion.

Specimens somewhat resembling the above, which were found by Mr. Clement Reid near Corfe Castle, and are now in the Museum of Practical Geology, are probably from the same locality, but the crystals do not appear to have been previously described.

Crystals showing the forms *f* and *x* appear to be rather uncommon, but some resembling fig. 1, from the Chalk of Saint-Julien-du-Sault (Dép. Yonne, France), were figured by Haüy,[1] and a search through the 2,500 published figures of calcite reproduced in Goldschmidt's 'Atlas der Krystallformen' has revealed seven other occurrences of crystals of similar type, of which two are British, viz. those at Pallaflat mine in Cumberland[2] and at Ashgrove quarry in Elgin.[3]

[1] R. J. Haüy, 'Traité de Minéralogie,' 1801, plate xxvii, fig. 42.
[2] S. L. Penfield and W. E. Ford, Amer. Journ. Sci., 1900, vol. x, p. 242.
[3] M. F. Heddle, 'Mineralogy of Scotland,' 1901, vol. i, plate xxv, fig. 54.

Communications from the Oxford Mineralogical Laboratory, No. XXV.

Barkevikite from Lugar, Ayrshire.

By Alexander Scott, M.A., B.Sc.

[Read November 10, 1914.]

In recent years a number of alkali-rich rocks have been described, containing barkevikite or 'barkevikitic hornblende.' So far as I am aware, however, no detailed examination has been made of the mineral since Brögger's work[1] on the original material from Barkevik in Norway, with the exception of the investigation by Michel Lévy and Lacroix.[2] Hence, when a rock was found amongst the Permo-Carboniferous rocks of Ayrshire, with comparatively large crystals of barkevikite, it was decided to examine it in some detail. The rock, which has been designated lugarite by Tyrrell,[3] occurs as thin veins and dykes intrusive into the picrite of the Lugar sill and as 'Schlieren' and irregular patches in the theralite of Barshaw, near Paisley. It has close affinities to the ijolites of Madagascar, and consists essentially of phenocrysts of barkevikite, titanaugite, and labradorite in a groundmass of analcite and nepheline, the two last-named minerals comprising about 50 per cent. of the whole.

The barkevikite occurs as black, lustrous, prismatic crystals, elongated parallel to the *c*-axis and up to three inches in length, the maximum thickness being about $\frac{3}{16}$ inch. The forms recognizable in the prism-zone are *b* (010) and *m* (110), while the terminal faces, which are much less regularly developed, include *c* (001) and a low pyramid which is probably *r* ($\bar{1}11$). Crystals twinned on *a* (100) are fairly common. The cleavage parallel to the prism *m* (110) is highly perfect, and cleavage fragments gave excellent signals on the goniometer. The mean value of

[1] W. C. Brögger, Geol. För. Förh. Stockholm, 1887, vol. ix, p. 269; Zeits. Kryst. Min., 1890, vol. xvi, pp. 412–415.

[2] A. M. Lévy and A. Lacroix, Compt. Rend. Acad. Sci. Paris, 1888, vol. cvi, p. 778; and 'Les Minéraux des Roches,' 1888, p. 148. Compare C. Hintze, 'Handbuch der Mineralogie,' 1894, vol. i, pp. 1254, 1257.

[3] G. W. Tyrrell, Geol. Mag., 1912, dec. 5, vol. ix, pp. 77–80.

ight measurements was 55° 36′, the limits being 55° 32′ and 55° 41′. 'his is fairly close to the value obtained by Brögger, namely 55° 44½′. 'here are also traces of a cleavage parallel to *b* (010).

The plane of the optic axes is the symmetry-plane and $\mathfrak{b} = b$. The xtinction-angles were measured on a number of sections, approximately arallel to *b* (010), of twinned crystals. The maximum value obtained was $: c = 11\frac{1}{2}°$, while several crystals gave values of 11°. Attempts were made o prepare prisms for the determination of the refractive indices, but these ailed, as the refracting edge always broke up as it became thin, owing to he perfect cleavages. The strong absorption prevented the use of cleavage-akes as prisms, the angle being too high for the images to be measurable. he mean refractive index was determined by immersing sections in mix-ures of methylene iodide and α-monobromonaphthalene, and was found o be approximately 1·690. The lowest value obtained was 1·680 and he highest 1·701. The maximum double refraction observed in any one ection was 0·018, but the true value of $\gamma - \alpha$ is probably a little above ·02. The optical sign is negative.

The optic axial angle was measured by means of the Fedorov stage, but he results obtained were only approximate, as the only sections avail-ble were those occurring in thin sections of the rock, the brushes being airly broad and somewhat indistinct on account of the strong absorption. The value of $2H_a$ obtained from seven measurements varied from 58° to 6°, with a mean value of 62°. As the refractive index of the glass hemi-phere used was 1·524, the value of $2V_a$ is 52°. The dispersion, both of he bisectrices and of the optic axes, is slight. The pleochroism is very ntense and is the most prominent characteristic of the mineral under the icroscope. The absorption is greatest for $\mathfrak{c}$ and least for $\mathfrak{a}$, the scheme eing $\mathfrak{c}$ very dark brown, $\mathfrak{b}$ reddish-brown, $\mathfrak{a}$ light yellow.

This scheme for the pleochroism is in agreement with that described y Brögger,[1] but differs from that of Michel Lévy and Lacroix,[2] who ound that there was a similar absorption for $\mathfrak{a}$ and $\mathfrak{b}$, instead of $\mathfrak{b}$ and $\mathfrak{c}$, s in the present case. The values of the refractive indices obtained by he latter authors were slightly higher than those given above, being = 1·687 and $\gamma = 1{\cdot}708$, but the amount of double refraction was prac-ically the same. The only previous determination of the optic axial ngle is one given by Rosenbusch,[3] who obtained the value $2E_a = 54° 18'$ y means of the Mallard method.

[1] W. C. Brögger, loc. cit.

[2] A. M. Lévy and A. Lacroix, loc. cit.

[3] H. Rosenbusch, 'Mikroskopische Physiographie,' 1905, vol. i (2), p. 236.

In general the optical properties of the Lugar mineral are in agreement with those of the barkevikite of Barkevik and Madagascar. The greenish-brown colour which appears in some sections of the mineral from Pouzac (Hautes-Pyrénées)[1] and Madagascar,[2] however, has not been observed in this case.

In order to obtain material for analysis, the rock was broken into coarse fragments, and the barkevikite picked out under a lens. This was then ground to a fine powder, and immersed in methylene iodide in order to eliminate apatite, which is the only important inclusion. The separated material was then washed with benzene and finally dried at 140° C. Column I in the following table gives the percentages by weight and column II the molecular percentages. Column III gives the analysis, by weight, of the Barkevik mineral.

		I.	II.	III.	IV.
SiO_2	...	42·48	46·81	42·46	38·41
TiO_2	...	2·90	2·38	—	—
Al_2O_3	...	8·58	5·55	11·45	17·65
Fe_2O_3	...	6·81	2·84	6·18	3·75
FeO	...	15·62	14·34	19·93	21·75
MnO	...	0·39	0·39	0·75	0·15
MgO	...	2·78	4·62	1·11	2·54
CaO	...	13·45	15·87	10·24	10·52
Na_2O	...	6·32	6·74	6·08	2·95
K_2O	...	0·60	0·46	1·44	1·95
H_2O	...	0·25	—	—	0·24
		100·18	100·00	99·64	99·91

I. Barkevikite from Lugar, Ayrshire. Sp. gr. 3·298.
II. ditto, molecular percentages.
III. Barkevikite from Barkevik, Norway. Analysed by G. Flink.
IV. Hornblende from sodalite-syenite from Square Butte, Montana. Analysed by W. H. Melville.

The agreement between I and III is fairly close, particularly with regard to silica, ferric oxide, and the alkalis. The Lugar mineral, however, has a noticeably lower content in ferrous oxide and a complementary excess of lime and magnesia. Brögger states that the silica

[1] A. Lacroix, Bull. Soc. Géol. France, 1890, sér. 3, vol. xviii, pp. 513–514; 'Minéralogie de la France,' 1893, vol. i, p. 665.

[2] A. Lacroix, 'Les roches alcalines caractérisant la province pétrographique d'Ampasindava.' Nouv. Arch. Mus. Hist. Nat. Paris, 1902, sér. 4, vol. i, p. 16.

in Flink's analysis contains the titanium dioxide. It seems much more probable that most of the latter is with the alumina. Hillebrand[1] is of the opinion that the residue left after volatilizing the silica with a mixture of sulphuric and hydrofluoric acids, may contain one-third of the total amount of titanium dioxide, but that it generally has less than this. As the earlier analyses of Plantamour and Rammelsberg[2] showed the 'Hornblende von Brevik' to have between one and two per cent. of oxide of titanium, this, if deducted from the alumina, would make the amounts of the latter more nearly alike.

Column IV gives the composition of a 'hornblende near barkevikite' from a sodalite-syenite described by Lindgren.[3] It shows considerable similarity to the other analyses in the relative amounts of ferrous oxide and lime, but differs from them in its higher content of alumina and smaller amount of alkalis.

An examination of the rock in which the barkevikite occurs, gives some indication of the conditions under which this mineral was formed. The crystals are exceedingly well developed and have obviously formed later than the titanaugite and labradorite, since euhedral crystals of the latter penetrate the barkevikite. The occurrence of the rock in veins and 'Schlieren' shows that, to some extent, it is a magmatic residuum and therefore comparable to the pegmatites in which the Barkevik mineral is found. The comparative rarity of the mineral, in general, is probably to be explained by the fact that it only forms in soda-rich rocks and through a limited temperature range, which seems to be fairly low. The lugarite magma must have remained mobile to a low temperature owing to its richness in water, and it is probably on this account, coupled with the composition, that the residual ferromagnesian material crystallized as barkevikite.

With regard to its position in the amphibole group, it seems to be intermediate between the basaltic hornblendes which characterize not only basalts but also such subalkalic rocks as tephrites, &c., and the titanamphibole which is typical of foyaitic and theralitic rocks. Barkevikite has a smaller content in sesquioxides and a greater amount of soda than the former, while it differs from the latter in containing less titanium dioxide and magnesia. In its richness in soda, it is related, not only to the titanamphiboles but also to arfvedsonite, with which it shows many similarities in composition and differs only in having less

[1] W. F. Hillebrand, Bull. U. S. Geol. Surv., 1910, No. 422, p. 96.

[2] Quoted by Brögger, loc. cit.

[3] W. Lindgren, Amer. Journ. Sci., 1893, ser. 3, vol. xlv, pp. 286–297.

ferrous oxide and soda. Optically, it is distinguished from arfvedsonite and the related katoforite,[1] by its much smaller extinction-angle and the absence of the characteristic blue-green colour. It therefore possesses sufficient characteristics, both chemical and optical, to justify its position as a separate species.

In conclusion, I wish to express my indebtedness to the Carnegie Trustees, as this work was done during the tenure of a Carnegie Research Scholarship.

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[1] W. C. Brögger, 'Die Eruptivgesteine des Kristianiagebiets,' 1894, vol. i, p. 27.

Communications from the Oxford Mineralogical Laboratory. No. XXVI.

Litharge from Zarshuran, Persia.

By Alexander Scott, M.A., B.Sc.

[Read November 10, 1914.]

THE specimen to which this paper refers, is one of a number of minerals from Kurdistan, presented to the Hunterian Museum, in Glasgow University, by Mr. D. Ferguson, to whom I am indebted for the following particulars of the occurrence. The exact locality is the Zarshuran River, in Kurdistan, where a large mineral vein, which has been worked for centuries for orpiment, is found. The country-rock is red sandstone, overlying, unconformably, altered slates and schists, which are intruded by a boss of felspathic granite or syenite. Near the surface the vein-stone is chiefly a kind of calc-sinter, but this disappears as the depth increases and calcite becomes the predominant mineral in the gangue, being associated with some quartz and fluorspar. The metalliferous minerals present, in addition to orpiment, include realgar, stibnite, a complex sulphide of antimony, lead, zinc, and iron, and the litharge which is to be described.

The specimen, which is about five inches in length and two in thickness, is coated with a white decomposition product which seems to be cerussite. One half of the material is composed of lustrous, red, mica-like flakes which are obviously crystalline, while the remainder, which is dull red in colour, appears to be massive. The streak is yellowish-brown and the hardness between 2 and 3. The weathered surface of the crystalline portion has a peculiar ribbed appearance, which is apparently connected with the sheaf-like arrangement of the thin flakes. There is no sharp line of demarcation between the two varieties, the laminated form gradually passing into the massive.

Under the microscope the laminae are seen to be translucent, the

colour being red in thick flakes, and yellow to yellowish-green in thin ones. There are two well-developed cleavages, perpendicular to each other, as well as several subsidiary sets of lines which appear to be glide-planes. One set of the latter is inclined to one of the cleavages at an angle of 18°–22° and another at 54°–58°. Measurements on a large number of fragments show these angles to be fairly constant within the limits mentioned. In thin sections the extinction is always straight with respect to the cleavages, and the mean refractive index, as determined by immersion in diluted methylene iodide, is $1{\cdot}735 \pm 0{\cdot}005$. The double refraction is fairly low and is probably somewhat less than 0·01, as 'yellow' sections show first order green and red interference-colours between crossed nicols and thinner ones first order yellow. In convergent light, these thin plates show a biaxial figure with a moderately wide angle, the optic axial plane being parallel to a cleavage, and the optical sign negative. There is no apparent pleochroism and the dispersion is fairly low. So far as the optical evidence goes, the mineral appears to be orthorhombic.

Some of the sections, which are sufficiently thick to appear red by transmitted light, appear to have different optical properties, being isotropic, or nearly so, between crossed nicols and giving, in convergent light, a figure which is either uniaxial, or biaxial with a very small angle. This phenomenon appears to resemble that obtained by Nörremberg[1] by the superposition of exceedingly thin plates of mica in such a way that their principal sections coincided. Such a combination behaves optically in the same way as a section of a uniaxial crystal cut perpendicular to the optic axis.

In the case of the litharge, the plates which are translucent are exceedingly thin, and can only be examined in minute fragments. Further, in some fragments, which are partly isotropic and partly doubly-refracting, the division between the two parts is generally a cleavage-plane, while the fact that the cleavages are parallel throughout indicates that the superposition, if such there be, cannot be oblique. Hence the most plausible explanation of the anomalous optical behaviour of these thicker plates is that it is due to overlapping, in some form or other, of very thin cleavage-flakes.

Some of the crystalline substance was picked out under a lens and an analysis, partly in duplicate, made of the material thus obtained, after allowing it to remain over sulphuric acid till it reached a constant weight. The results obtained were as follows:

[1] Cf. P. Groth, 'Physikalische Krystallographie,' 4te Aufl., 1905, p. 149.

	(*a*)	(*b*)	Mean.
PbO ...	97·04 ...	97·30 ...	97·17
CuO ...	2·70 ...	2·53 ...	2·61
Sb_2O_3 ...	0·30 ...	— ...	0·30
P_2O_5 ...	trace ...	— ...	trace
CO_2 ...	trace ...	— —	trace
	100·04		100·08

Qualitative tests for lead peroxide, PbO_2, were made, but none was found. Iron oxide was also proved to be absent. The analyses show the mineral to be nearly pure litharge. The specific gravity is 8·61.

Occasionally, plates, which are obviously unaltered by weathering, show under the microscope minute dendritic growths of black material in the midst of the yellow crystalline substance. These skeletal growths bear a remarkable resemblance to the crystallites which commonly occur in metallic alloys, and particularly to those which form in eutectiferous mixtures where one constituent is in excess. It therefore seems probable that the crystallites represent either the excess of copper oxide which the lead oxide is incapable of taking up in solid solution, or else the excess of copper oxide over the eutectic mixture of the two oxides. Of these, the former explanation is the more probable.

Hintze[1] states that lead oxide is not known to occur in a crystalline state in nature, but is found in scaly, granular, and earthy forms. The only analyses in the literature are two by Pugh[2] of rather impure material from Mexico. Several occurrences in Mexico have been recorded, but the crystalline nature of the material in all cases is somewhat doubtful.

Two crystalline modifications have been prepared synthetically, but their conditions of equilibrium have not been definitely determined, while there is also some doubt regarding the optical properties. The two varieties can be prepared by dissolving lead oxide in molten potassium hydroxide, yellow crystals being obtained with rapid cooling and red ones with slow cooling. This would point to the latter modification being the stable one at ordinary temperatures. Luedecke[3] found that

[1] C. Hintze, 'Handbuch der Mineralogie,' 1910, vol. i, p. 1934.

[2] E. Pugh, Inaug.-Diss., Göttingen, 1856; quoted in Hintze, loc. cit. An early analysis by J. F. John (1812) is quoted in Dana's 'System of Mineralogy,' 5th edition.

[3] O. Luedecke, Zeits. Kryst. Min., 1884, vol. viii, pp. 82–83. Numerous references to previous literature are given.

the red variety was tetragonal, while the yellow one was orthorhombic. Termier[1] investigated the orthorhombic form in some detail and found that it was pseudo-cubic with a refractive index above 1·8, strong double refraction, and sensible pleochroism. The tetragonal form has not, so far, been investigated further.

As there seems to be some confusion regarding the two forms, an examination was made of some synthetic crystals of the red variety. These were bright red under a lens, but under the microscope thin sections appeared yellow. Two good cleavages were visible and extinction was straight with regard to them. In convergent light a decidedly biaxial figure was obtained, the optical sign being negative. This material, therefore, is very similar to the natural mineral from Persia, save that the glide-planes and optical anomalies are absent. Some of the red crystals were melted and allowed to cool fairly quickly. A very fine-grained yellow crystalline product resulted, and this, under the microscope, appeared greenish. The crystals, however, were too minute for further examination.

The Persian mineral seems to be crystalline litharge, and its optical properties are in agreement with those of the red synthetic variety which was examined. As previous investigators simply describe the red form as tetragonal without any mention of it being yellow by transmitted light in thin section, there is obviously some confusion as to the nature of the two varieties. The whole question of the polymorphism of lead oxide requires a thorough re-investigation before our knowledge of it can be regarded as satisfactory.

Under these circumstances it is somewhat difficult to give any satisfactory explanation of the origin of the mineral. It was most probably derived from the oxidation of the lead-bearing sulphides which are common in the vein ; but it is impossible to give any account of how this oxidation could be brought about.

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[1] P. Termier, Bull. Soc. franç. Min., 1895, vol. xviii, pp. 367–380.

The determination of the maximum extinction-angle, optic axial angle, and birefringence in twinned crystals of monoclinic pyroxenes in thin section by the Becke method.

By Harvey Collingridge, B.Sc., F.G.S., A.M.I.C.E.

[Read November 10, 1914.]

IN nearly every thin section of a rock containing monoclinic pyroxenes it will be found that one or more crystals twinned on the orthopinacoid (100) are included. In such crystals the twin-plane is marked very clearly by the difference of relative retardation and extinction, and also by the interference-bands if the twin-plane is inclined to the plane of section. For the purposes of the complete optical determination, it is essential for the proposed method that one half of the twin should exhibit the emergence of an optic axis suitable for the determination of the optic axial angle by the Becke method.[1] Let the crystal in which the axis is visible be denoted by (1) and the other half of the twin by (2).

The observations to be made on crystal (1) are:

(*a*) The position of the trace of the optic axial plane.

(*b*) The position of the visible optic axis.

(*c*) The extinction-angle relative to (*a*).

These three observations are necessary for the determination of the optic axial angle.

(*d*) The position of the trace of the twin-plane relative to (*a*).

The observations to be made on crystal (2) are:

(*e*) The position of the trace of the optic axial plane, if possible.

(*f*) The position of an optic axis, if possible.

(*g*) The extinction-angle relative to (*a*).

(*h*) The birefringence of the section.

The observations (*g*) and (*h*) are essential.

All the above data must be plotted on a stereographic diagram. It will be obvious that (*e*) should be the same as (*a*), as the twinning is on (100) and the optic axial plane is at right angles to this face. On the stereogram let:

WABE represent the optic axial plane.

AB the optic axial angle as determined for crystal (1).

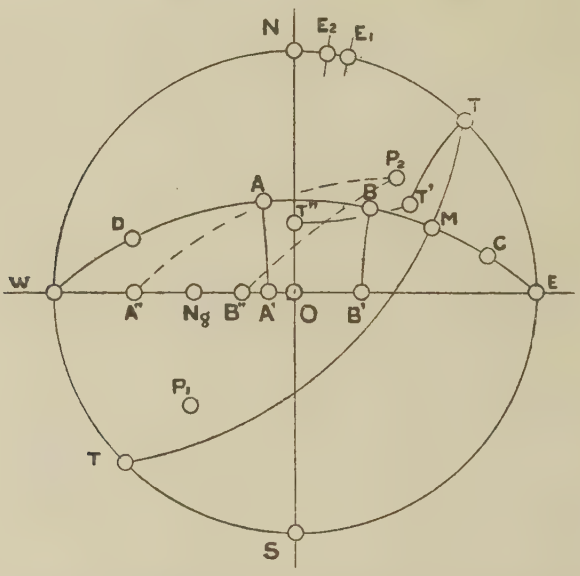
[1] See H. Collingridge, Mineralogical Magazine, 1913, vol. xvi, p. 348.

TT the trace of the twin-plane.

OE_1 the direction of extinction for crystal (1).

OE_2 the direction of extinction for crystal (2).

The next proceeding is to bring the trace of the optic axial plane at right angles to the plane of the diagram by revolving it the requisite amount to bring the optic axes A and B on to the EW diameter at A' and B'. The point T which is on the circumference of the base circle will also move along a small circle to T', and the twin-plane will then be represented by the great circle $NT'S$. The diagram must now be



revolved on the NS diameter the correct angle to bring the point T' on to the NS diameter at T''. This operation brings the twin-plane at right angles both to the plane of the diagram and the plane of the optic axes, and the points A' and B' will move along the EW diameter to A'' and B''.

Let the angle $A''B''$ be bisected at N_g, thus marking the acute bisectrix. The maximum extinction-angle ($c : \gamma$) is now measured by the angle N_gO, where O is the centre of the base circle.

The revolutions about the NS and EW diameters will have moved the original normal to the section of the crystal (1) to a point P_1. The complementary pole P_2 of crystal (2) will consequently be situated in a similar position in the diagonally opposite sector of the stereogram. The

maximum birefringence of the mineral may now be found by dividing the birefringence (h) of crystal (2) by the sines of the angles P_2A'' and P_2B'' according to the approximate formula. As in most cases these angles will be large, the determination will be of a fair degree of accuracy.

Reverting now to the original trace of the optic axial plane $WABE$, we can set off an angle BM equal to the angle $B''O$, the point M thus marking the point where the twin-plane cuts the optic axial plane. On the great circle $WABE$ set off an angle MC equal to MB and on the other side of the twin-plane. The point C will therefore mark the position of an optic axis of crystal (2). Also as the optic axial angle AB has already been determined from observations on crystal (1), the position D of the second optic axis of crystal (2) can be marked off.

A check on the work is furnished by the line of extinction OE_2 of crystal (2) which should bisect the angle COD, according to the Biot-Fresnel law. The accuracy of these determinations would appear to be of about the same order of accuracy as the determination of the optic axial angle.

In the accompanying diagram the angles $2V = AB = 43°$ and $N_gO = c : \gamma = 45°$, and the birefringence $N_g - N_p = 0{\cdot}027$ were determined for a pleochroic augite in dolerite from Craighead, Perthshire.

On hollow spiral prismatic crystals of ice on the surface of snow.

By L. Leigh Fermor, D.Sc., A.R.S.M., F.G.S.
Geological Survey of India.

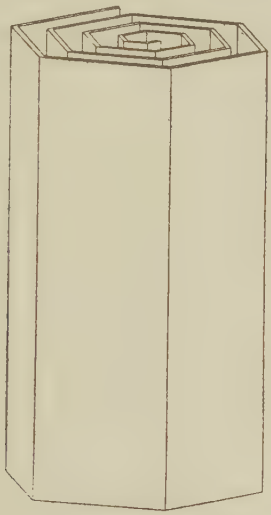
[Read June 16, 1914.]

LAST winter I enjoyed the good fortune of spending some three months at Zweisimmen in the Bernese Oberland of Switzerland, in order to participate in the winter sports. Happily it proved a fine, cold winter of hard frosts and moderately heavy total snowfall. During such a stay in the crisp, dry cold of a snow-mantled world, the manifold and beautiful forms assumed by snow and ice are set before one in a manner impossible in this relatively warm and moist isle with its fleeting glimpses of true wintry weather. According to their size, the streams become frozen up or roofed over with ice, and the waterfalls congealed into cascades of icicles or covered with an icy curtain, behind which a much-diminished volume of water continues to fall. The snow-fields do not remain as when freshly formed, but are subject to constant change. In the earlier hours of the morning, while the sun is still low, the snow surface is dry, crystalline, and but loosely coherent, and the advancing skis of the ski-runner push their way through a sand of brilliant, pure white snow crystals, sparkling like myriads of diamonds, but towards midday and in the afternoon, the intense heat of the sun's direct rays melts the surface of the snow, although the temperature itself remains below zero (Centigrade); and to the ski-runner the snow now feels sticky, often rendering his progress uncertain. As the sun declines and its rays leave the snow, the water wetting the snow crystals or granules begins to freeze again, and by the next morning the surface of the snow has become rejuvenated with a wondrous growth of ice crystals, most commonly with fern-like forms, built, of course, on a hexagonal plan, and analogous to the familiar frost-growths on window-panes, but very much more delicate and intricate, and developed in three dimensions instead of two.

The portions of snow-fields lying in shady situations do not, of course, suffer this diurnal surface melting, except when, during warmer weather,

the temperature of the air rises above zero. During a prolonged spell of fine cold weather, the surface crystals gradually increase in size until the 'fern-fronds' may be as much as one-half to one inch across. These additions to the crystals are derived, it must be supposed, from the moisture of the atmosphere, by direct condensation during the intense cold of night.[1]

But the crystals on the surface of the snow do not always adopt this fern-like habit. Another habit is that which forms the subject of this



Crystal of ice.

note, in which the entire surface of the snow in shady situations may consist of a *cheval de frise* of small hollow hexagonal prisms, composed each of a thin sheet of ice coiled round the vertical axis in a hexagonal spiral parallel to the faces of a hexagonal prism. This is the habit illustrated in the accompanying figure. These prisms range in size from perhaps $\frac{1}{4}$ to $\frac{3}{4}$ inch in length, with a maximum diameter of $\frac{1}{8}$ inch. This gives but a small thickness to the walls of a prism containing three or four coils, and it will easily be understood that an ordinary pocket-lens is not powerful enough to permit the determination with certainty

[1] Temperatures as low as $-12°$ to $-17°$ C. at 8 a.m. were common at Zweisimmen, which lies in a valley at only 945 metres, or roughly 3,000 feet, above sea-level. It may be presumed that still lower temperatures would be recorded on the surrounding mountains.

of the nature of the terminating faces. Consequently, although in the figure the prism is represented as terminated by the basal plane, I cannot assert the invariable absence of other faces. The ratio between length and breadth shown in the figure is, perhaps, an average one, but the prisms may be either more slender or more squat.

It is difficult to indicate any particular condition, either physical or meteorological, as determining the formation of these hollow prisms rather than the commoner fern-like growth, but it may be of interest to record the situation of the largest field of hollow prisms noticed.

On December 4, 1913, before the winter's snow and frost had finally established themselves, I walked to Lenk, some eight miles from Zweisimmen, and thence onwards towards the Simmen Fall at the head of the valley of the Simme. The portion of this valley between Lenk and the fall, a distance of about $2\frac{1}{2}$ miles, lies at about 1,100 metres above sea-level, is flat, and occupied by fields and the hamlet of Obeeried. The final mile or so of this portion of the valley lies in the shadow of the Wildstrübel mass, a section of the Oberland range rising to heights of over 3,000 metres; at 2 p.m. Oberried was in shade and, according to an inhabitant, does not see the sun for some three months in the winter. At the time of my visit the fields of Oberried were occupied by a continuous sheet of snow several inches thick, although at Lenk and Zweisimmen all the previously-fallen snow had been melted or evaporated away. I had been at Zweisimmen since the 21st of November, and there had been several falls of rain in the interval, with very little snow. But a fairly heavy fall of snow had taken place a few days before my arrival, and it is probable that the main mass of the Oberried snow dated from this early fall, and had been protected from melting by the Wildstrübel mass, which seemed to me not only to shade the snow from the direct rays of the sun, but also to ensure a lower air temperature than at Lenk only $1\frac{1}{2}$ miles away. This snow-field had, therefore, probably been in existence for some $2\frac{1}{2}$ to 3 weeks at the time of my visit, but had doubtless received small additions of snow corresponding to rainfall elsewhere. Wherever I examined this field it was covered with a bristling growth of the hollow hexagonal prisms noticed above. On continuing my walk past the Simmen Fall, and rising over 1,000 feet up the Ammerten Pass, through ever-deepening snow, I found the snow universally surfaced with the prismatic growth, and everywhere in shade. The prismatic growth must have been formed since the last fall of snow, which probably took place only a few days before my visit, and, in the absence of diurnal melting, the water required must have been drawn from the atmosphere.

Later in the season I often noticed limited areas of this prismatic growth, usually in the shade of trees, but was not able to assign a reason for its formation, instead of the commoner fern-like growth, which is found both in the shade and in the sun.

The probability that both prismatic and fern-like growths are largely due to abstraction of moisture from the atmosphere seems to be indicated by the fact that they both form as hoar-frost on twigs and branches bared of snow by a previous thaw ; these, if situated in the shade, escape a diurnal melting, and continue to grow day by day, so that in two or three days twigs become coated with a bristling array of hollow prisms or a feathery growth of 'fern-fronds'.

The manner in which the surface of a snow-field may grow during a snow-drought was well shown in a field at Zweisimmen, where people had written their names in the snow with a walking-stick by the side of a path leading to the skating-rink. The act of writing had ridged up the displaced snow along the edge of the letters nearer the path, and during a prolonged spell of fine weather the ridged-up portions increased gradually in height, so that writing originally about an inch deep became bordered by a raised ridge of about the same height, which doubly emphasized the writing. This field was in the sun, but the weather being very cold the amount of snow melted in the day was small, and probably balanced by the growth at night. The water doubtless tends to sink into the snow during the day, but, later, any still liquid water must be sucked up by capillarity to the growing ridges, to be accentuated still further by moisture condensed from the atmosphere in greater abundance on the projecting ridges than on the flat surface of the surrounding snow.

There is a considerable volume of knowledge concerning the forms of newly-fallen snow crystals, of which many hundreds of varieties have been figured by various authors, as for example by William Scoresby,[1] by G. Nordenskiöld,[2] and by W. A. Bentley.[3] None of these resemble at all closely the crystals referred to in this note, which is not surprising, when it is realized that the hollow prisms are related in mode of formation to hoar-frost rather than to crystals of newly-fallen snow. Indeed the forms of hoar-frost seem to have been much less studied than snow crystals. However, I have succeeded in finding one comparable case. Dr. Karl

[1] W. Scoresby, 'An Account of the Arctic Regions,' 1820.

[2] G. Nordenskiöld, 'Communication préliminaire sur une étude des cristaux de neige.' Bull. Soc. franç. Min., 1893, vol. xvi, pp. 59–74.

[3] W. A. Bentley, Nature, 1902, vol. lxv, p. 234.

Grossmann and the late Mr. J. Lomas[1] have given an account of varieties of hollow pyramidal ice crystals formed as hoar-frost—i.e. by condensation direct from the atmosphere—in (1) the lava cavern of Surtshellir in Iceland; (2) as ordinary hoar-frost in the north of England; (3) on the under surfaces of ice crusts on ruts and ponds; and (4) in refrigerators. These crystals are commonly hollow hexagonal pyramidal hoppers attached by their points, with the open ends pointing into the enclosed air space or to the open sky, according to circumstances. Writing of the hoar-frost noticed in various parts of Yorkshire, Lancashire, and Cheshire, in Christmas week 1892, the authors say: 'A spiral arrangement was noticed in some cases, and occasionally a double spiral resembling the helix of an Ionic capital.' This latter variety is figured, and it is seen that the spirals are pyramidal and not prismatic. On examination the authors found that these various types of hopper-shaped crystals were not really hexagonal pyramids, but that each triangular face was built up of a stepped alternation of faces of the hexagonal prism with the basal pinacoid, the very forms recognized in the spiral prisms of Switzerland here described. These authors regard the hopper-shaped crystals as starvation crystals, the pyramidal expansion of the hoppers being due to the fact that the interiors of the hoppers attempt to draw their moisture from only a limited volume of air compared with that adjoining the exterior of the crystals. Our Swiss hexagonal prisms must be regarded as another form of starvation crystal.

In the present paper only two general forms of snow growths have been referred to, but others exist, and it would probably be well worth the while of a mineralogist visiting Switzerland or Scandinavia during the winter to take with him a microscope for crystallographic study.

[1] K. Grossmann and J. Lomas, 'On hollow pyramidal ice crystals.' Nature, 1894, vol. 1, pp. 600–602.

A new locality for Voelckerite and the validity of Voelckerite as a mineral species.[1]

By Austin F. Rogers.

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[Read June 16, 1914.]

IN 1912 the writer[2] proposed the name voelckerite (in honour of Dr. John Augustus Voelcker, the well-known English agricultural chemist, who made important contributions to our knowledge of the chemistry of apatite) for the basic calcium phosphate, $3Ca_3(PO_4)_2.CaO$, related to apatite. The fact that apatite is often deficient in fluorine and chlorine was proved by Voelcker[3] and by Hoskyns-Abrahall,[4] both of whom gave as the general formula of apatite $3Ca_3(PO_4)_2.Ca(F_2,Cl_2,O)$ or its equivalent $Ca_{10}(PO_4)_6(F_2,Cl_2,O)$. Carnot[5] also noted the deficiency of chlorine and fluorine in apatite from Tyrol, but he offered no explanation. Rammelsberg,[6] in a paper published shortly before his death, assumed the existence of the compound $Ca_{10}P_6O_{25}$ (equivalent to $3Ca_3(PO_4)_2.CaO$) to explain the chemical composition of various apatites, though he thought the presence of this molecule was due to alteration. This explanation is very improbable, for these minerals are perfectly fresh and homogeneous.

[1] With the addition of some new observations, this paper presents in an amplified form a portion of the material of the author's earlier (1912) paper on the minerals of the apatite group.—Ed.

[2] A. F. Rogers, 'Dahllite (podolite) from Tonopah, Nevada; vœlckerite, a new basic calcium phosphate; remarks on the chemical composition of apatite and phosphate rock.' Amer. Journ. Sci., 1912, ser. 4, vol. xxxiii, pp. 475–482; translation in Zeits. Kryst. Min., 1913, vol. lii, pp. 209–217.

[3] J. A. Voelcker, Ber. Deutsch. Chem. Gesell., 1883, vol. xvi, p. 2460.

[4] J. L. Hoskyns-Abrahall, Inaug.-Diss., Munich, 1889. Abstract in Zeits. Kryst. Min., vol. xxi, p. 389.

[5] A. Carnot, Bull. Soc. franç. Min., 1896, vol. xix, p. 135.

[6] C. F. Rammelsberg, Neues Jahrb. Min., 1897, vol. ii, p. 37.

Groth[1] substitutes hydroxyl for oxygen and gives the formula $(PO_4)_3(Cl,F,OH)Ca_5$. He has been followed by Lacroix, Naumann-Zirkel, and others.

Since the brilliant work of Penfield[2] on the isomorphous replacement of fluorine by hydroxyl in triploidite, amblygonite, topaz, herderite, and other minerals one would expect *a priori* that the deficiency in the fluorine and chlorine content of apatite might be explained by the presence of hydroxyl. The published analyses do not bear this out, for the water content of the hypothetical hydroxy-apatite (1·80 per cent.) is greatly in excess of that found in the minerals in question. The highest percentage of water ever recorded in apatite is only 0·48 per cent. In this apatite from Ceylon, which was described from Jannasch and Locke,[3] there is still a deficiency in the combined ratios of fluorine, chlorine, and hydroxyl. The ratios of $P_2O_5 : R''_2O : (F,Cl,OH)$ are 3 : 10·8 : 1·68, as against the theoretical ratios 3 : 10 : 2 required by the formula $3Ca_3(PO_4)_2.Ca(F_2,Cl_2,[OH]_2)$. This is apparently a very accurate analysis. If the water is constitutional it may prove that hydroxyl replaces fluorine and chlorine, but it equally proves that oxygen replaces fluorine. As the water content of these apatites is usually very low (the average of four analyses of Zillerthal specimens made by Hoskyns-Abrahall is only 0·20 per cent.) the water may be hygroscopic or dissolved water instead of water of constitution. The water content of these minerals needs close inspection for two reasons. (1) It is a well-known fact that water of constitution is not given off until very high temperatures are reached. (2) Penfield and Minor[4] have proved that in the presence of fluorine, hydroxyl may be given off as hydrofluoric acid or hydrofluosilicic acid instead of as water. These two points have been borne in mind in the preparation of this paper and will be taken up later.

The Zillerthal apatite may be taken as the type of voelckerite. This mineral occurs in large euhedral crystals of thick tabular habit which often attain a diameter of six or eight centimetres. On the specimens, from this locality, which were examined for the present investigation, the only associated mineral noted is a thin film of chlorite. Koenigs-

[1] P. Groth, 'Tab. Uebersicht der Mineralien,' 4th edit., 1898, p. 87. Note also Groth's remark (speaking of apatite), 'Die Existenz freien CaO ist theoretisch höchst unwahrscheinlich, dagegen wäre eine Ersetzung von Fl durch HO wahrscheinlich.' (Zeits. Kryst. Min., 1886, vol. xi, p. 107.)

[2] S. L. Penfield, Amer. Journ. Sci., 1878, ser. 3, vol. xvi, p. 45; 1879, vol. xviii, p. 295; 1886, vol. xxxii, p. 107; 1894, vol. xlvii, p. 387.

[3] P. Jannasch and J. Locke, Zeits. Anorg. Chem., 1894, vol. vii, p. 154.

[4] S. L. Penfield and J. C. Minor, Amer. Journ. Sci., 1894, vol. xlvii, p. 388.

berger[1] in similar occurrences in Tyrol mentions adularia, albite, quartz, epidote, fluorite, calcite, and zeolites. The crystal forms present on the large voelckerite crystals are: c (0001), m (10$\bar{1}$0), x (10$\bar{1}$1), s (11$\bar{2}$1), and r (10$\bar{1}$2). On a smaller crystal minute faces of the forms μ (21$\bar{3}$1), n (31$\bar{4}$1), v (11$\bar{2}$2), and a {11$\bar{2}$0} were identified by the reflection goniometer. The symmetry, then, is hexagonal equatorial (A_6.P = hexagonal dipyramidal class) like fluor-apatite, for (31$\bar{2}$1) and (41$\bar{3}$1) are absent. The mineral is white, subtranslucent, with an imperfect basal (0001) and prismatic (10$\bar{1}$0) cleavage. The specific gravity is 3·10 and the hardness about 5. The index of refraction determined by the Becke method is 1·634 ± 0·005. The double refraction, determined by grinding down a prismatic section alongside a basal section of barite, is about 0·003.

A number of analyses of the Zillerthal apatite made by Hoskyns-Abrahall[2] are on record, but carbon dioxide is not included. In view of the fact that Carnot[3] had found that the carbonate radical replaces fluorine in a number of apatites, it was thought that perhaps the carbonate radical had been overlooked in the Zillerthal mineral. It was partly with this idea in view that Mr. G. E. Postma, then a chemistry student at Stanford University, made a careful analysis of the Zillerthal mineral with the following results:

Analysis of Voelckerite from Zillerthal, Tyrol, by G. E. Postma.[4]

					Molecular ratios.		
CaO	55·73	Ca	39·83	0·994	...	10	
P_2O_5	42·65	PO_4	57·07	0·601	...	6	
CO_2	0·16	CO_3	0·23	...	...		
F	1·20	F_2	1·20	0·032			
H_2O	0·30	$(OH)_2$	0·56	0·016	0·089	...	1
		O	0·65	0·041			
	100·04						
Less O for F_2	0·50						
	99·54		99·54				

This analysis is given in both the form of ordinary oxides and metals and acid radicals. The oxygen which replaces the fluorine is obtained by

[1] J. Koenigsberger, Neues Jahrb. Min., 1901, Beil.-Bd. xiv, pp. 43–119.
[2] J. L. Hoskyns-Abrahall, loc. cit.
[3] A. Carnot, loc. cit.
[4] In A. F. Rogers, Amer. Journ. Sci., 1912, vol. xxxiii, p. 479.

subtracting the percentages of calcium and acid radicals from the percentages of the ordinary oxides. The small amounts of carbon dioxide and water are probably due to liquid inclusions with gas bubbles which are observable in thin sections with a high power objective.

In the analysis given above no special precaution was taken to avoid water being given off as hydrofluoric acid. Supplementary water determinations of the same lot of specimens have recently been made by the writer. The Penfield method[1] for water determination was used. The powdered mineral was placed in the end of a Jena glass tube wrapped with platinum foil. At a convenient distance from the end ignited lead oxide (PbO) enclosed by glass-wool was heated by means of an auxiliary burner. The mineral was heated at the highest heat of a blast-lamp for about an hour. The water collected at the cool end of the tube (a moistened cloth served to condense it). The tube was melted off and the water determined directly by weighing the tube plus water, then drying and weighing again. The water content was 0·113 per cent. With ignited lime (CaO)[2] instead of lead oxide, the water content was 0·109 per cent.

This is pretty good proof that the Zillerthal mineral has the composition $3Ca_3(PO_4)_2.Ca(O,F_2)$ with oxygen predominating over fluorine. An analysis of the Zillerthal mineral given by Hoskyns-Abrahall is even closer to the theoretical for voelckerite, as the fluorine content is only 0·62 per cent. and the water content 0·15 per cent. The excess oxygen content is correspondingly higher.

Most of the chlorine-bearing apatites from Norway show a deficiency in chlorine, while fluorine is absent and water (or hydroxyl) is present in very small amounts. The theoretical quantity of chlorine in chlor-apatite being 6·80 per cent., Voelcker's analyses prove that many of the Norwegian apatites are really voelckerite, as excess of oxygen predominates over chlorine. Other analyses of Norwegian apatites made by Voelcker and Waage gave respectively 5·06 per cent. and 5·8 per cent. of chlorine. It is remarkable that pure chlor-apatite has never been found.

If hydroxyl and fluorine, or hydroxyl and chlorine, were isomorphous in the above apatites, the hydroxyl would decrease as fluorine or chlorine increased, but no such relation is apparent. For this reason the existence of the compound $3Ca_3(PO_4)_2.Ca(OH)_2$, even as a replacing molecule, is

[1] S. L. Penfield, Amer. Journ. Sci., 1894, vol. xlviii, pp. 30–37.

[2] The lead oxide and lime are probably superfluous, for the water content is no greater with them than without.

very doubtful. The water may be in solid solution, as in tremolite and other minerals.[1]

The writer has recently discovered voelckerite in Calaveras valley, a small valley north-west of Mt. Hamilton and east of Milpitas, Santa Clara county, California. It occurs in vein-like patches of coarse anhedra in a massive metamorphic rock composed of glaucophane, omphacite, chlorite, garnet, and titanite. If the garnet were more prominent the rock would be called an eclogite. The rock in which the voelckerite occurs is one of patchy outcrops of glaucophane-bearing rocks of the Franciscan series of the Coast Ranges of California. These and similar rocks have been described by J. P. Smith.[2]

The voelckerite is a white, subtranslucent mineral with imperfect cleavage and faint lustre. The specific gravity is 3·06, and the hardness about 5. In a thin basal section a negative uniaxial interference-figure was obtained. A roughly rectangular section with maximum interference colour for the slide has elongation parallel to the slower ray, which indicates that the mineral occurs in subhedral crystals of tabular habit. The index of refraction determined by means of the Becke test with respect to liquids of known indices of refraction is 1·634 ± 0·005. The double refraction is about 0·005, using glaucophane to determine the thickness of the slide.

The following chemical analysis of the Calaveras valley voelckerite was made by Mr. G. W. Jordan under the writer's direction. Each result (except Al_2O_3) is the mean of two closely agreeing values.

Analysis of Voelckerite from Santa Clara County, California.

				Molecular ratios.		
CaO	54·46	Ca	38·42	0·983	1·025	10
Al_2O_3	1·35	Al	0·71	0·039		
FeO	0·24	Fe″	0·19	0·003		
P_2O_5	41·47	PO_4	55·47	0·584	0·584	6
H_2O	0·22	CO_3	0·35	0·006	0·111	1
CO_2	1·03	OH	0·41	0·012		
Insol.	0·53	O	1·49	0·093		
		Insol.	0·53	—		
	99·30		97·57			

As in the Zillerthal analysis, the excess oxygen is determined by difference. The microscopic examination proves that the carbonate radical

[1] See E. T. Allen and J. K. Clement, Amer. Journ. Sci., 1908, vol. xxvi. p. 101.

[2] J. P. Smith, Proc. Amer. Phil. Soc., 1907, vol. xlv, pp. 183–242.

is due in whole or in part to admixed calcite. An attempt was made to determine the carbonate present as calcite by dissolving the powdered mineral in warm (about 70° C.) very dilute (1 : 8) hydrochloric acid. A little of the voelckerite was also dissolved[1] by the dilute acid, but as a separate sample was used this could not seriously affect the result. The analysis indicates that 1·04 per cent. of the carbonate radical belongs to calcite, and the remainder perhaps to voelckerite. If we subtract 1·04 per cent. of CO_3 and an equivalent amount of Ca (0·69) we have the figures given in the second column. The molecular ratios are very closely $(Ca + Al_{2/3} + Fe'') : PO_4 : (O + CO_3) = 10 : 6 : 1$. As the molecule $3Ca_3(PO_4)_2.CaO$ predominates, the mineral must be called voelckerite.

As there was a chance that the mineral had not been heated sufficiently to drive off all the water, careful water determinations at high temperatures were carried out by the writer. As an extra precaution[2] lead oxide was used, as in the determination of water in the Zillerthal mineral. Two determinations, made with hard glass heated for an hour with a blast-lamp, gave 0·197 and 0·214 per cent. of water, which agree very well with Mr. Jordan's determination of 0·22 per cent. (average of 0·17 and 0·26).

There are hints that voelckerite may frequently occur in metamorphic rocks. Turner,[3] for example, states that apatite occurring in a biotite-gneiss from the North Fork of the Mokelumne River, California, tested by Hillebrand, showed the absence of both fluorine and hydroxyl and very little chlorine. A thin section of this gneiss contains an accessory mineral which would ordinarily be called apatite.

The evidence of a number of apatite analyses, including several in which special care was taken in the water determinations, proves that the compound $3Ca_3(PO_4)_2.CaO$ is the predominant molecule in many minerals of the apatite group. There is no proof that the compound $3Ca_3(PO_4)_2.Ca_2(OH)$ exists as the predominant molecule in any apatite, and it is also doubtful whether it exists as a replacing molecule.

The discovery that in many minerals fluorine and hydroxyl are isomorphous, instead of fluorine and oxygen as held by Rammelsberg, was one of the brilliant achievements of Penfield.[4] Rammelsberg, up to the very last, maintained that oxygen and fluorine were isomorphous. It

[1] The voelckerite is also slightly soluble in hot water.

[2] The results prove this precaution was unnecessary.

[3] H. W. Turner, Amer. Journ. Sci., 1902, vol. xiii, p. 343.

[4] S. L. Penfield, Amer. Journ. Sci., 1878, vol. xvi, p. 45.

looks as though he may have been correct in a single instance. It is probable, in the light of recent work in chemical mineralogy, that in ordinary compounds hydroxyl and fluorine are isomorphous. Apatite, however, is complex in composition, and it is probable that the compound $3Ca_3(PO_4)_2.CaO$ is isomorphous with $3Ca_3(PO_4)_2.CaF_2$, because of the mass-effect of $3Ca_3(PO_4)_2.Ca$ with a formula weight of 971. This is a reasonable explanation, for it does no violence to the isomorphism of hydroxyl and fluorine in ordinary compounds. The idea of mass-effect isomorphism we owe also to Penfield.[1]

There is no reason why hydroxyl should not occur in apatite. There is simply lack of evidence that it occurs, except in trifling amounts. In the mineral svabite, $3Ca_3(AsO_4)_2.CaF_2$, the arsenate analogue of fluor-apatite, the water percentages are only 0·25 and 0·33, yet there is a great deficiency in the fluorine and chlorine content. In the mineral fermorite, a strontium-bearing arsenical apatite, described by Smith and Prior,[2] only a trace of water is given in the analysis, yet the fluorine (F = 0·83 per cent.) is deficient, and the formula is written

$$3[(Ca,Sr)_3(P,As)_2O_8].Ca(OH,F)_2.$$

If the compound $3Ca_3(PO_4)_2.CaO$ exists it deserves a distinctive name. Voelckerite is preferable to the name oxy-apatite suggested by analogy with fluor-apatite. The name voelckerite is similar to voelknerite, but the latter is a synonym of hydrotalcite, so no longer needs to be used except as a synonym. The question arises as to what names shall be used for other members of the apatite group. The name apatite may be reserved for fluor-apatite or applied as a group name for calcium phosphate minerals of the type $3Ca_3(PO_4).CaX_2$. The latter is perhaps preferable to the former on account of the difficulty of distinguishing the individual minerals without an accurate chemical analysis. The general tendency with increase of knowledge is to divide minerals into species. Formerly mica, feldspar, mesotype, uranite, were considered individual minerals; they are now group names.

If apatite is the group name, we have the names fluor-apatite, chlor-apatite, dahllite (podolite), and voelckerite. Dahllite, or podolite, was previously called carb-apatite, but the name was withdrawn. As I have suggested elsewhere,[3] it is advisable to restrict combined chemical and arbitrary names such as soda-orthoclase, silver-analcite, carb-apatite, &c.,

[1] S. L. Penfield, Amer. Journ. Sci., 1899, vol. vii, p. 118.

[2] G. F. H. Smith and G. T. Prior, Mineralogical Magazine, 1911, vol. xvi, p. 84.

[3] A. F. Rogers, Proc. Amer. Phil. Soc., 1913, vol. lii, pp. 610, 612.

to artificially-prepared compounds and hypothetical compounds or end-members of isomorphous series. In this case new names should be given to fluor-apatite and chlor-apatite. This has been done in many other cases. Barbierite was formerly soda-orthoclase, autunite was lime-uranite, genthite was nickel-gymnite, &c.

Conclusions.

Many minerals of the apatite group are deficient in combined fluorine and chlorine. This deficiency has generally been explained by assuming the compound $3Ca_3(PO_4)_2.Ca(OH)_2$. It is, however, more probable that the compound has the composition $3Ca_3(PO_4)_2.CaO$ for the following reasons:

(1) The water percentage in apatite is too small for the compound $3Ca_3(PO_4)_2.Ca(OH)_2$.

(2) In analogous minerals such as svabite and fermorite the water percentage is also very low.

(3) There is no correlation between the amounts of hydroxyl (or water) and combined fluorine and chlorine.

(4) The exception to the general rule of the isomorphism of fluorine and hydroxyl may be easily explained by mass-effect isomorphism.

For a mineral with the composition $3Ca_3(PO_4)_2.CaO$, or one in which this molecule predominates, the name voelckerite may be used.

Apatite is a group name for four distinctive minerals, viz.:

Fluor-apatite	...	$3Ca_3(PO_4)_2.CaF_2$
Chlor-apatite	...	$3Ca_3(PO_4)_2.CaCl_2$
Dahllite (podolite)	...	$3Ca_3(PO_4)_2.CaCO_3$
Voelckerite	...	$3Ca_3(PO_4)_2.CaO$.

The similarity in the properties of these minerals may be explained by mass-effect isomorphism.